

Misc. Paper No. 37

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

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WINGS WITH VARIABLE CAMBER AND SLOTS

By J. Lacaine

L'Aeronautique, May 1933

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Washington  
August 1933

## WINGS WITH VARIABLE CAMBER AND SLOTS\*

By J. Lacaine

Investigations with a view to increasing the  $C_{z_{\max}}$  of a wing, without greatly increasing the  $C_{x_{\min}}$ , are chiefly related to the important question of the maximum speed range.

Mr. Lacaine, Mr. Toussaint's assistant at the Saint Cyr aerodynamic laboratory, has tackled the problem by adding a slot effect to the simultaneous variation of the camber and area of a wing. The solutions studied are in two parts, no description of the actual devices being given below.

One part is given up to the study of rotations and translations by which slots and a simultaneous increase of the camber and wing area are produced. The other part deals with rotations of elements with respect to each other only. These rotations form two slots of adjustable width in the wing section.

Wind-tunnel tests of two models are described below. The test results are compared with the estimated results based on the theory of wings with multiple ailerons. Lower-surface flaps of a special form, resembling split flaps, are also described.

### WING WITH A SINGLE VARIABLE SLOT

The rear wing portion (fig. 1) is displaced with respect to the front section in such a manner that, with two of its points, A and B, describing eccentric circles, a variable slot is formed. The tested wing section, with a relative thickness of 24 percent, has a high maximum lift of  $100 C_{z_{\max}} = 260$ . However, as was to be expected, its  $C_{x_{\min}}$  is rather high and the L/D ratio not very good (fig. 2).

Tests, based on the same principle, made by Mr. Fowler in an American wind tunnel (reference 1), seem to show the

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\*"Ailes a courbure et fentes variables." L'Aeronautique, May 1933.

great superiority of semi-thick wing sections. These preliminary results may be improved by another series of tests of these wing sections.

#### WING WITH VARIABLE CAMBER AND SLOTS

The wing section is in five parts, four of which are hinged (fig. 3). The rotations of parts A and B produce two slots and help to increase the camber of the section. Two small flaps, C and D, on the upper wing surface, control the width of the slots and retard the separation of the boundary layer at large angles of attack. The deflections of parts A, B, C, and D are expressed by the angles  $\alpha$ ,  $\beta$ ,  $\gamma$ , and  $\delta$ .

#### TESTS RESULTS

Determination of  $C_{x_{min}}$ .— After eliminating the drag of the control units and making allowance for the discontinuities about the slot edges on the lower wing surface, a value of 1.4 was found for  $100 C_{x_{min}}$ , which may be reduced to about one by masking the slot edges with elastic flaps. It would then approach the minimum drag of the original wing section 13'A, which has a relative thickness of 17 percent according to the catalog of the French Technical Service.

Classification of the results.— Three series of tests were made in order to determine the influence of the position of the slots and of the increase in camber on the characteristics of the airfoil:

Forward slot only (rotation of sections A and C),

Rear slot only (rotation of sections B and D),

Front and rear slots (rotation of A, C, B, D).

The increase of  $C_{z_{max}}$  due to the slots, can be calculated by comparing the unit curves  $100 C_z = f(i)$  (fig. 4) (reduced to the incidence of the forward portion), which correspond to various settings with and without slots. The gain over the  $C_{z_{max}}$  of the airfoil cambered without slot increases with the camber.

The representative points of the envelope polar are found by taking two or three points on each side of the intersection of OI with the  $100 C_z = f(i)$  curves, for successive deflections of the movable parts. OI is the straight line connecting the point O of zero lift with the point of  $C_{zmax}$  maximorum  $10^\circ$ .

## COMPARISON WITH THEORY OF WINGS

### HAVING MULTIPLE AILERONS

We have compared these test results with those of the theory of wings having multiple ailerons, as developed by Mr. Perring (reference 2) and already applied by Mr. Tous-saint. Without going into details, the nondimensional coefficients  $C_z$  and  $C_m$  are given by

$$C_z = a_1 \left[ i + \left( \sum_1^p \lambda_s \tau_s \right) \right]$$

$$C_m = \frac{C_z}{4} + \left( \sum_1^p m_s \tau_s \right)$$

$a_1 = C_{ze}/i^\circ$ , being the angular coefficient of the straight portion of the  $100 C_z = f(i)$  curves;  $p$ , the number of ailerons;  $\lambda_s$  and  $m_s$ , coefficients easily calculable from the chord of the various ailerons;  $\tau$ , the angle representing the various deflections.

In the present case we have, for  $i = 0^\circ$ ,

$$C_z = 0.54(0.9\alpha + 0.7\beta)$$

and

$$C_m = \frac{C_{ze}}{4} + (0.165 \alpha + 0.315 \beta) \frac{2}{57.3}$$

the angles about the two hinge points being  $\alpha$  and  $\beta$ .

It is remarkable that the difference between the calculated and the measured  $C_z$  values does not exceed 10 per cent for deflections of sections A and B reaching  $20^\circ$ .

## COMPARISON OF SLOTTED WINGS

In order to compare the relative merits of the variable-camber and slot solution with the results of other systems, we have plotted in fig. 5 the polars, L/D curves and moments of:

A wing with forward slot of the fixed-flap type;

A wing with movable forward flap and Handley-Page slot in the rear;

A wing with variable camber and slots.

The three models were tested in the same tunnel, at the same Reynolds Number, and the respective curves reduced to the aspect ratio of 6.

The wing with variable camber and slots has the best L/D ratio and the wing with front and rear slots has the highest  $C_{zmax}$ , while the wing with fixed forward slot has a still better L/D curve than the other two, within the range of the mean angles. As regards the moments, the  $C_{m0}$  of the last-named wing does not approach the origin, although having a less pronounced slope than the other two.

## COMPARISON OF SLOTTED FLAP

## WITH REAR LOWER-SURFACE FLAP

Among the recently investigated devices for increasing the maximum lift, the rear upper-surface flap (split-flap) seems to be particularly favored by certain American airplane designers. Its principle is to split the trailing edge into two sections, one forming the lower-surface flap and the other, consisting of the upper surface of the trailing edge, being integral with the wing. Wind-tunnel tests of this system (reference 3) show that the lift values obtained by deflections of a lower-surface flap exceed those usually produced by standard flaps of the same chord. It seemed to be of interest to compare these lift values with those produced by the same wing fitted with a slotted flap.

A fixed metal sheet, representing the upper surface of the initial wing section (fig. 6) was therefore secured to the model, flaps A and B (fig. 3) being then subjected to various combined deflections. The slots produced by rotations of these flaps can be opened or closed by means of the small upper-surface flaps C and D.

The following are the main results obtained: As shown by the American tests, the drag of the rear lower-surface flap, for the same  $C_z$ , considerably exceeds that of the conventional split flap. A slot between the lower wing surface and the region of small velocity, which extends from the flap to the fixed trailing-edge portion, reduces the drag, but also the  $C_z$  (max).

A comparison of the  $C_z$  (max) (fig. 7) shows that the lower-surface flap offers a certain advantage due to its small size (flap B - 0.3 c; c = wing chord), while the slots resulting from the simultaneous deflection of flaps A and B ( $\alpha = 20^\circ$ ,  $\beta = 20^\circ$ ) produce much higher maximum lift values (220 instead of 195).

Lastly, beyond  $C_z$  (max) the decrease in lift is much greater with the lower-surface flap than with the slotted flap. The latter seems therefore to be better suited for flight at large angles of attack.

A judicious choice between these two systems calls for a measurement of the longitudinal moments and of the hinge moments, in addition to the above comparison, and for a structural investigation to determine the easier of the two solutions.

## CONCLUSION

The main results of this study may be summarized as follows:

1.  $C_{z\max}$  values exceeding 260 (first model) are attained by wings with a single slot and variable camber and area.

2. Semi-thick wings, with an aspect ratio of 6, a single rotational slot and an upper-surface flap, have the following characteristics:

$$100 C_{x_{\min}} = 1.4$$

$$100 C_{z_{\max}} = 190$$

$$100 C_m \text{ for } C_z = 0:0$$

$$C_z/C_{x_{\max}} = 176$$

The  $C_{z_{\max}}$  may be increased to 240 (second model) by adding another slot.

3. The slot effect is directly proportional to the camber.

4. The formulas obtained for wings with multiple ailerons agree well with practical results.

5. Slotted flaps and a rear lower-surface flap (split flap) were tested on the same wing. With large, simultaneously deflected flaps, the slotted wing has a greater maximum lift than when it is fitted with a split flap.

Translation by W. L. Koporindó, Paris Office,  
National Advisory Committee for Aeronautics.

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2. Perring, W. G. A.: The Theoretical Relationships for an Aerofoil with a Multiply Hinged Flap System. R. & M. No. 1171, British A.R.C., 1928.
3. Weick, Fred E. and Harris, Thomas A.: The Aerodynamic Characteristics of a Model Wing Having a Split Flap Deflected Downward and Moved to the Rear. T.N. No. 422, N.A.C.A., 1932.

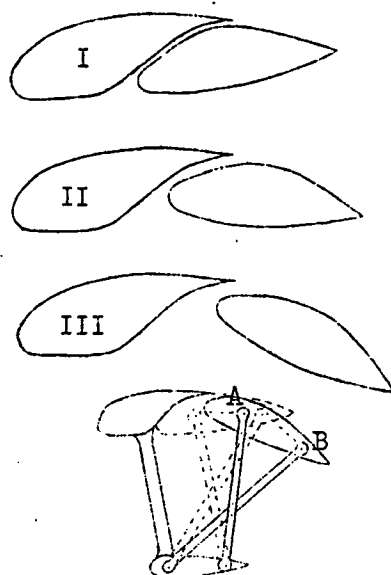


Figure 1.-Wing with variable slot.

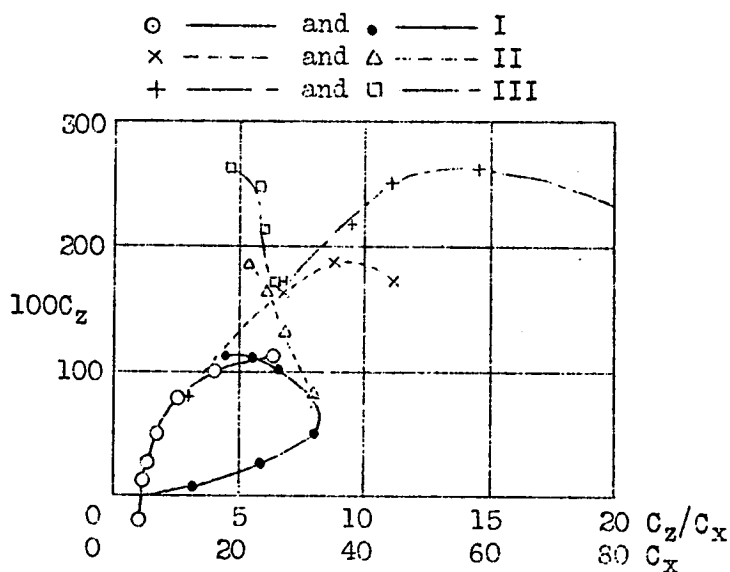


Figure 2.-Polar and L/D ratio of the three wing sections of fig. 1. The  $100 C_x$  values are plotted on half the conventional scale. The area of reference is that of the initial wing section (I).



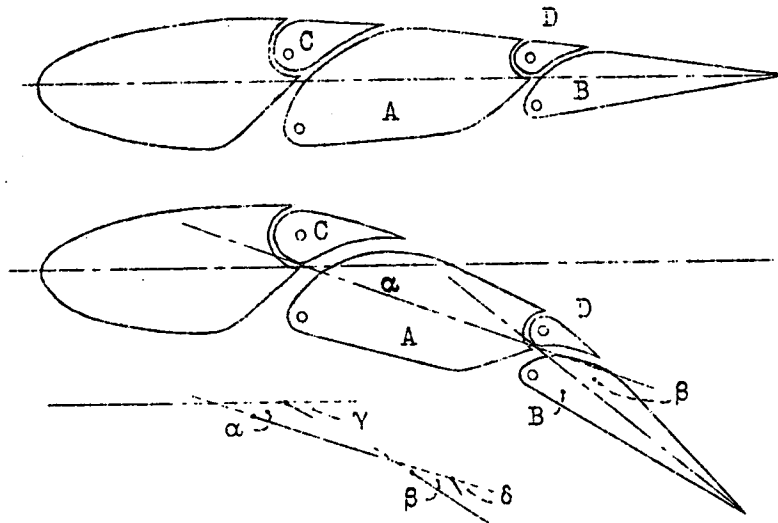


Figure 3.—Showing hinge points and deformations of wing section with variable camber and slots. The upper wing section has no slot. The intervals between C and A and D and B are merely intended to improve the representation of the contours.

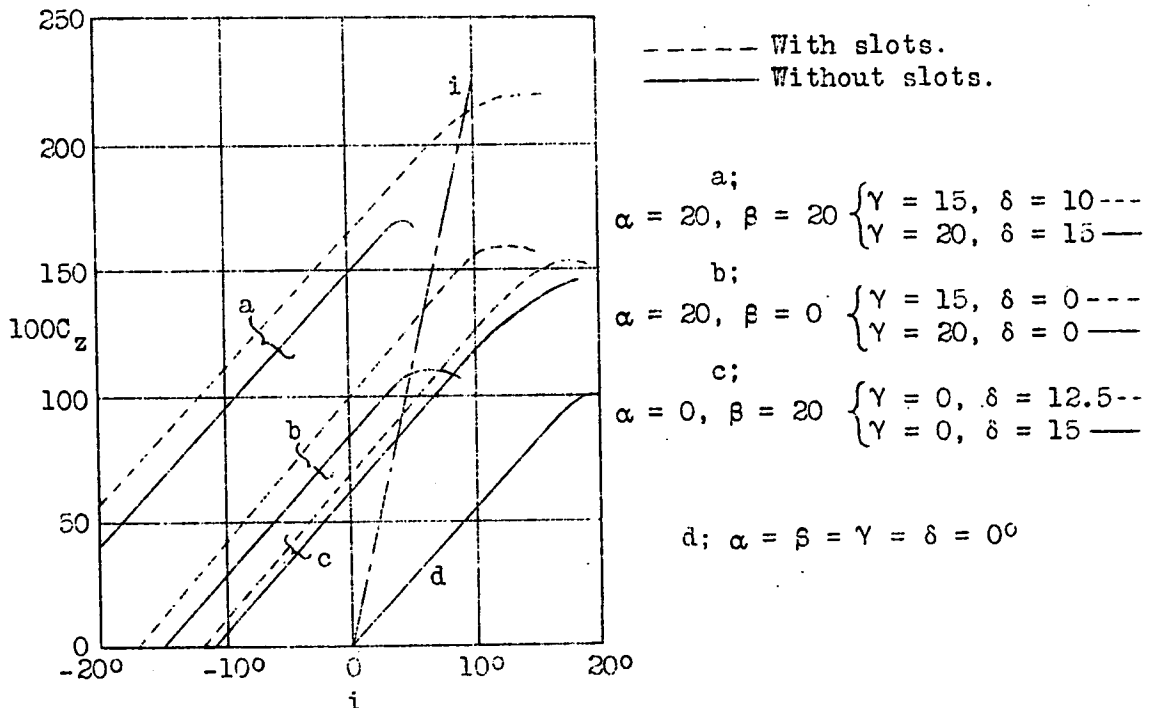


Figure 4.—Comparative lifts of equally cambered airfoils, with and without slots.

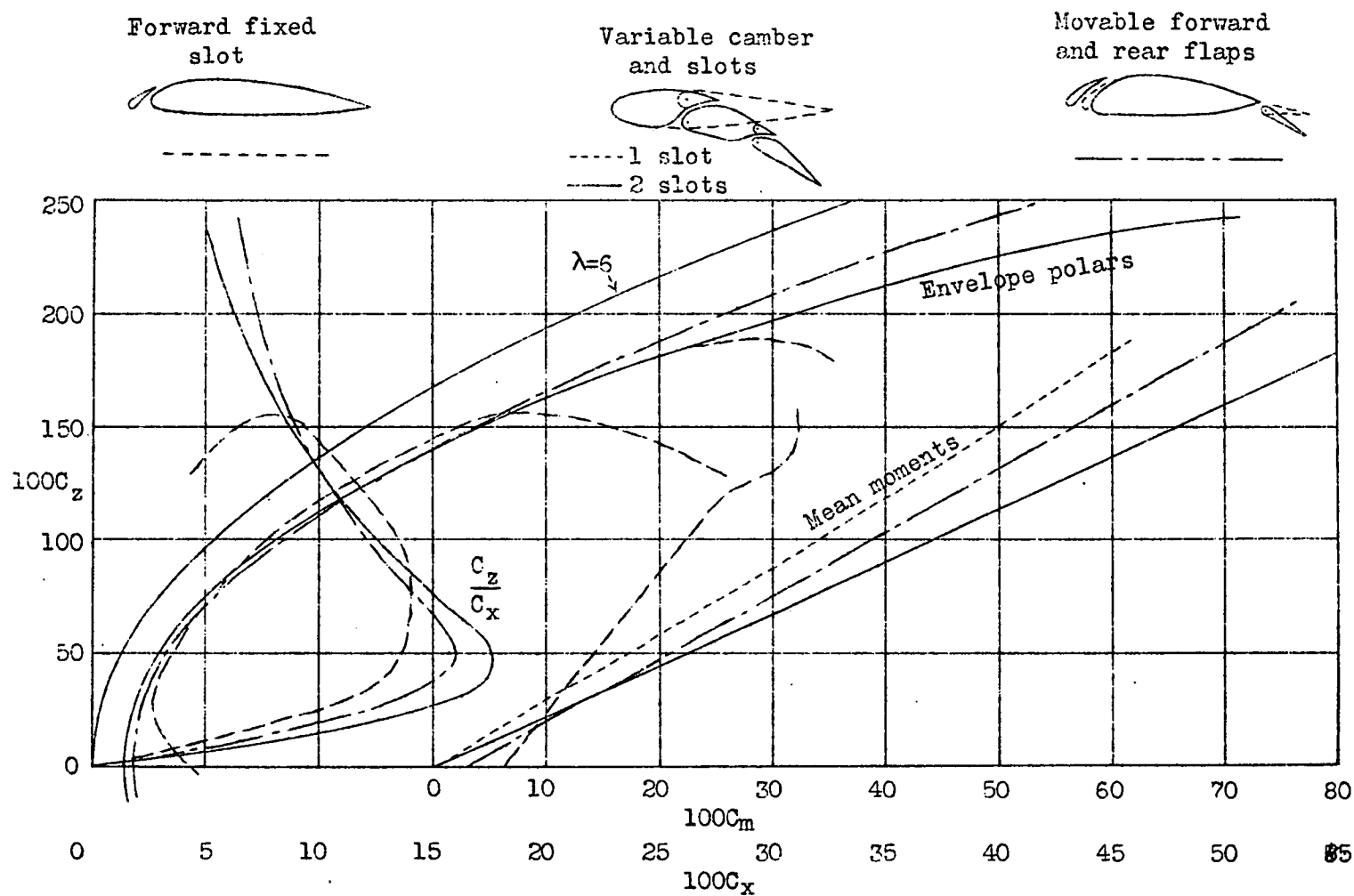


Figure 5.—Comparison of polars, moments and  $C_z/C_x$  curves of wing section with fixed forward slot, of a wing section with variable front and rear slots and of a wing section with variable camber and slots.

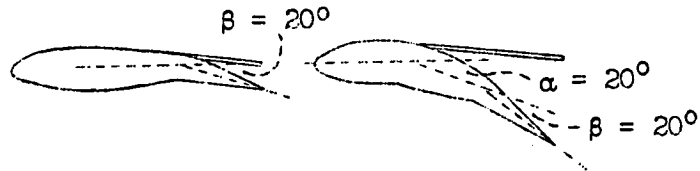


Figure 6.—Transformation of original Lacaine model by an auxiliary plane flap forming an extension of the upper wing surface.

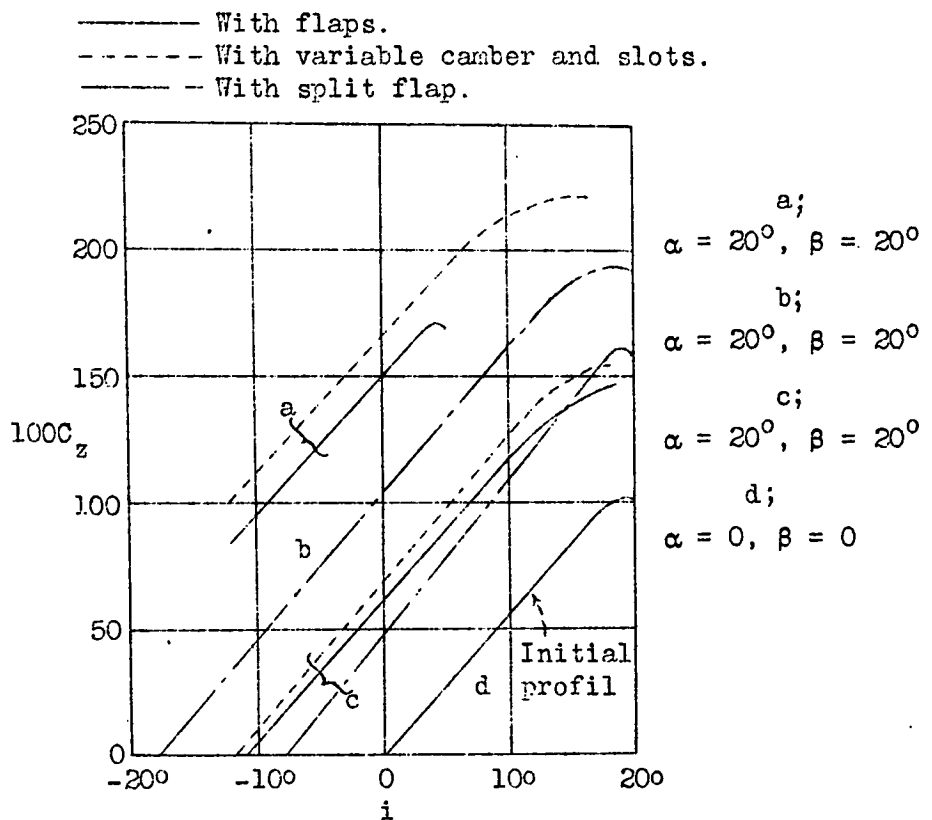
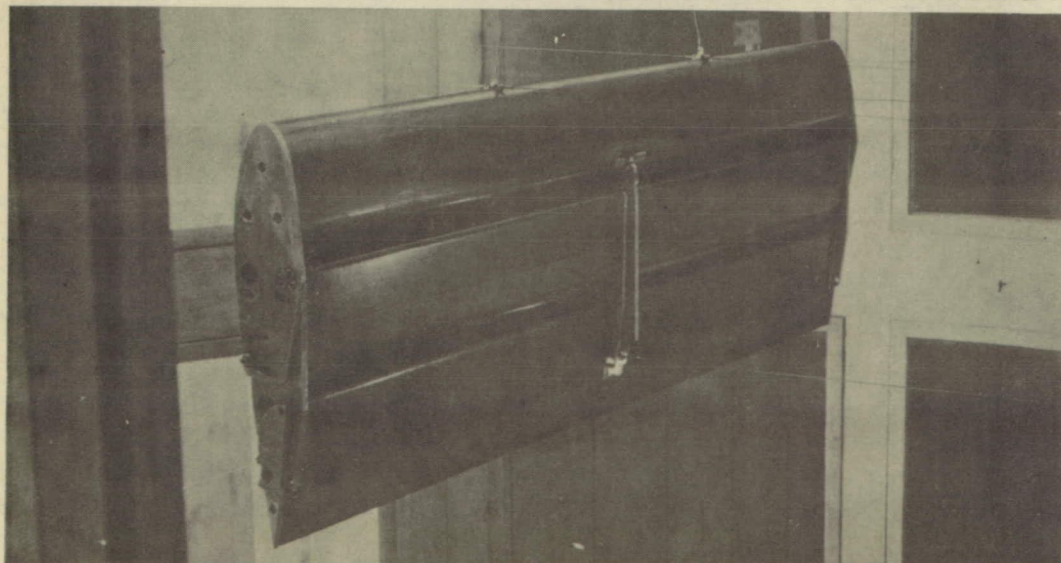
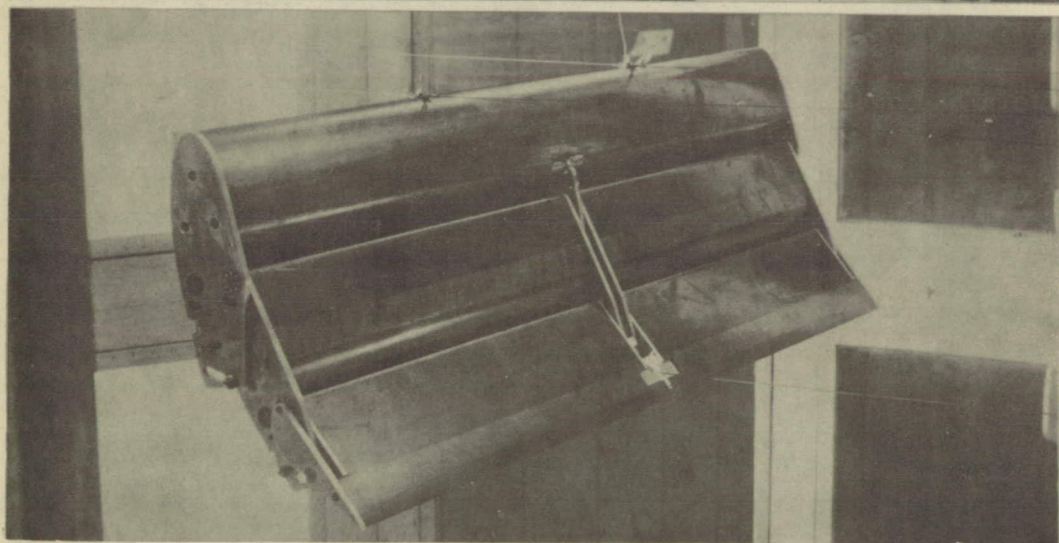
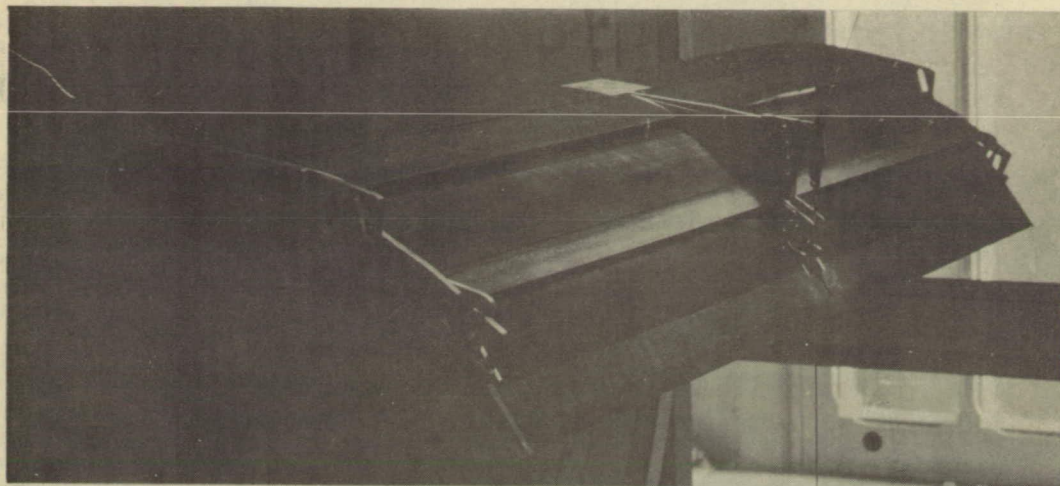


Figure 7.—Comparison of lift values of wing sections with flaps, with variable camber and slots, and with split flap, for equal flap settings.



Figures 8,9,10.-Photographs of wing with variable camber and slots mounted in the Saint-Cyr wind tunnel.